THE POISONOUS EFFECTS OF CIGARETTE-SMOKING.

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THE fact that cigarette-smoking produces physiological effects differing to some extent from those of the cigar has led me to make the experiments which I record here, tending toward an explanation of it. The frequently ascribed cause of the difference: that of the adulteration of cigarrette tobacco with opium and other drugs and also the presence of arsenic in the paper are for many reasons unsatisfactory and insufficient. It is true, no doubt, that the tobacco in many of the less expensive brands is adulterated with cheap drugs and artificial flavors and that in the more expensive grades opium may be used; but I believe it to be equally true that many cigarettes are made of tobacco which is free from sophistication. The presence of arsenic in the paper is entirely out of the question.

Before describing the experiments in detail, I shall discuss "smoking" in general. In "smoking" it is, of course, necessary that the tobacco should undergo combustion to a greater or less degree.

The principal elements found in tobacco are carbon, hydrogen, nitrogen and oxygen, and, of these, the carbon and hydrogen are combustible, while the nitrogen and oxygen are non-combustible.

Besides combustion, destructive distillation takes place in the pipe, cigar or cigarette, as the result of the heat and the exclusion of the oxygen of the air which has been completely used up in passing through the red-hot burning tobacco, in front of that which the fire has not yet reached. The products of this destructive distillation are ammonia, a yellow and very poisonous substance of disagreeable odor, called nicotianine, some nicotine (but most of the latter has been destroyed by the heat) and many other products of minor importance.

The result of the combustion of the hydrogen referred to previously is water; and the products of the combustion of the carbon are carbonic acid gas, or carbon dioxide, and carbonic oxide, or carbon monoxide. Carbon dioxide is the result of the complete combustion of carbon, and carbon monoxide is the result of the semi-combustion of carbon.

What is known, then, as tobacco smoke is a mixture of the products of combustion and of destructive distillation of the tobacco with the nitrogen of the air. The products of the combustion of the carbon predominate, if measured by volume, and of these carbon monoxide is in excess of carbon dioxide for the following reason: When carbon is burned in an excess of oxygen the result is carbon dioxide, and when this carbon dioxide comes in contact with red-hot carbon it is deoxidized and carbon monoxide is

formed. This is seen in the combustion of charcoal, coke or anthracite in a grate or stove; the air passes through the grate bars and comes in contact with the red-hot carbon and carbon dioxide is formed; this gas is impelled by the draught to pass through the bed of glowing coals, and, in so doing, it is reduced to carbon monoxide, which, when it reaches the top, encounters a draught of air and burns with a pale blue, lambent flame, becoming oxidized to carbon dioxide again. This is similar to what takes place at the end of a cigar or cigarette or in a pipe, where there is a layer of fire from $\frac{1}{64}$ to $\frac{1}{16}$ of an inch in thickness, and as the air is drawn through it, carbon dioxide is first formed; on passing through the hot carbon this is reduced to carbon monoxide, and, as such, it is drawn into the mouth, for when it passes beyond the fire there is no air or oxygen to convert it back to carbon dioxide.

Now let us consider the properties of these products of the combustion of carbon: carbon dioxide will neither burn nor support combustion. It fails to support life, but is not poisonous; it simply produces death by suffocation. On the other hand, carbon monoxide does not support combustion, but burns with a pale blue flame. It fails to support life because it is extremely poisonous, and this is due to the affinity which it has for the hemoglobin of the blood. It has the power to expel all of the dissolved and loosely combined oxygen from the blood, and it converts the oxyhemoglobin into carbonic-oxide-hemoglobin, which, of course, results

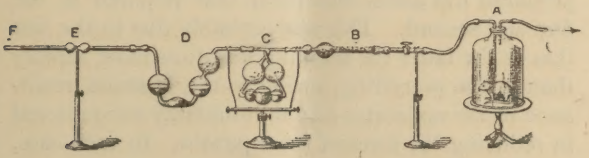
in death. The blood thus affected acquires a florid arterial hue, which differs from the normal color of the blood by its persistence. An animal plunged into an atmosphere of carbonic oxide, dies instantly, and, when small quantities mixed with air are breathed, headache, giddiness and insensibility readily occur. Death from carbonic oxide is easily proved by a spectroscopic examination of the blood of the victim.

There is a difference in the methods of smoking a cigarette and a cigar or pipe. In the two last-mentioned, the smoke is simply drawn into the mouth and expelled directly therefrom or through the nose, while the experienced cigarette-smoker will inhale the smoke—that is, draw it to a greater or less extent into the air-passages and in some cases to the greatest depth of the lungs, and thus the absorption of the carbonic oxide and other gases will take place very rapidly, causing more or less deoxidation of the blood and thereby impairing its power to build up the wasting tissues of the body.

Acting upon this theory I proceeded to experiment on animals and obtained for the purpose some mice. The animal to be experimented with was placed in a glass bell-jar, into which the smoke of a cigarette mixed with air could be drawn as rapidly as desired by means of a laboratory aspirator.

In the first experiment the smoke was purified as much as possible, and the atmosphere breathed by the animal was practically oxygen, nitrogen and carbonic oxide. The apparatus employed is shown in the accompanying figure.

The cigarette F was loosely inserted in the end of the tube E having two bulbs. D and C are bulbs containing a solution of potassium hydrate to absorb the carbon dioxide and any acids or condensable bodies not deposited in E. B is a tube containing solid potassium hydrate broken into small lumps, which retained any carbon dioxide that may have escaped the bulbs C and D. The animal was placed



in the bell-jar and the apparatus connected together as shown in the figure. The aspirator, which was connected with the rubber tube leading from A, was turned on so as to draw a slow current of air through the apparatus in the direction indicated by the arrow. The cigarette was then lighted and in twenty-two minutes the animal was dead.

On examination of the blood of the animal by the spectroscope it was found that all of the oxyhemoglobin had been converted into carbonic-oxide-hemoglobin, which showed that carbonic oxide was the cause of the death. This experiment was repeated and the result was the same; the animal died in twenty-five minutes, and the spectroscope revealed the same condition of the blood.

A third experiment was made without the bulbs C and D and the tube B. The tube E, carrying the

cigarette F, was connected directly to A, and thus the smoke was drawn into the bell-jar without the removal of any of its original constituents. In this case the animal died in six minutes, and the examination again showed that the carbonic oxide was the immediate cause of death, proving that it was the most noxious constituent of the tobacco smoke. The time required to produce death in the last experiment was about one-fourth that required in the first and second. This was probably due to the fact that in the latter the smoking was done more rapidly than in the preceding, owing to the lessened resistance in the apparatus and the difficulty encountered in reducing the force of the aspirator. In each case, however, the amount smoked up to the time of death was about the same, one and one-fourth cigarettes.

From these experiments I feel justified in drawing the following conclusions:

1. That carbonic oxide is the most poisonous constituent of tobacco smoke.

2. That more injury results from cigarette than cigar- or pipe-smoking, because, as a rule, the smoke of the former is inhaled.

3. That cigarette smoking without inhaling is no more injurious than pipe- or cigar-smoking.

4. That the smoke of a cigar or pipe, if inhaled, is as injurious as cigarette smoke inhaled.

5. That the smoke from a Turkish pipe, if inhaled, is as injurious as that of a cigarette inhaled.

In these experiments I was ably assisted by Mr. W. J. Pulley, who was at the time doing special work in physiological chemistry under my direction.

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